FINAL REPORT TO THE JOINT FIRE SCIENCE PROGRAM

Project Title: Re-measurement of fuels and stand structure 13 years after logging of the Summit Fire, Malheur National Forest, eastern Oregon

Joint Fire Science Program ID Number: 11-1-1-19

Principle Investigators:

James McIver, Senior Research Associate Professor, Eastern Oregon Agricultural Research Station, Oregon State University, Union, OR

Roger Ottmar, Research Forester, Fire and Environmental Research Applications Team, Pacific Northwest Research Station, Seattle, WA

Abstract

This final report describes the results of the project 'Re-measurement of fuels and stand structure 13 years after logging of the Summit Fire, Malheur National Forest, eastern Oregon' (Project 11-1-1-19), which was funded in the amount of $298,476 by the Joint Fire Science Program under Task Statement 1 of FA-RFA-11-1, '**Re-measurement Opportunities'**. The Task Statement sought proposals to "re-measure existing field studies to assess the effects of high-severity fire on vegetation succession, and/or to evaluate the effects of post-wildfire management".

We re-measured fuels, stand structure, and understory vegetation on plots of the Summit post-fire logging study in the summer of 2011, 15 years after the 1996 Summit Fire burned 16,000 ha of seasonally dry mixed conifer forest on the Malheur National Forest in eastern Oregon. The southern third of the Summit Fire area is dominated by ponderosa pine forests, and here the 1996 wildfire burned with unusual severity, killing more than 80% of the trees, even in stands that had been intensively managed over the previous 40 years (USDA 1997). In the summer of 1998, two years after the fire, the Malheur National Forest conducted a timber sale, in which several thousand hectares of forestland was logged, including four replicated blocks of stands within which we measured the effects of logging on erosion and sediment transport (McIver 2004), soil disturbance (McIver and McNeil 2006), and fuels and stand structure (McIver and Ottmar 2007). Recent observations of the logged stands at Summit have indicated that soil disturbance effects have become blurred by vegetation re-growth, and that the risk of sediment transport out of stands has largely disappeared, indicating that the benefit of re-measuring these variables is minimal at this time. On the other hand, the fuel bed and stand structure have changed markedly since post-fire logging measurements were last taken (Figure 1), even though no vegetation or fuel reduction management has taken place in the ensuing years. One block of treated stands however (Wray Creek Block 4; Figure 2), experienced an additional wildfire in the summer of 2008, thus distinguishing it from the original replicated experiment, and turning it into a case study. We therefore re-measured stand structure, understory vegetation, and the fuel bed, to capture information on fuel mass changes, snag fall rate, log decay rate, and regeneration success since the fire of 1996 (15 years hence), since the logging of 1998 (13 years hence), and for the Wray Creek block, since the second wildfire of 2008.

In this final report, we describe findings from the 2011 re-measurement of all plots, and present our accomplishments in the context of the deliverables promised in the 2011 proposal.

Background and Purpose

Why is it important to study the intermediate (5-20 years) and long-term effects of post-fire logging on fuels and stand structure? In general, large investments are made annually in post-wildfire management, including post-fire logging, without robust information on the effects of implemented activities. In particular, with respect to stand structure and the fuel bed, despite the conventional wisdom that removal of standing dead wood might reduce ground fuels and hence the risk of a severe re-burn at some point in the future ('Re-burn' Hypothesis; Poff 1989), very little scientific information is available to test this idea. McIver and Starr (2001) found that by early 2000, only 21 studies worldwide had examined the environmental effects of post-fire logging, 14 of which had an unlogged control, and just seven of which were replicated

Figure 1

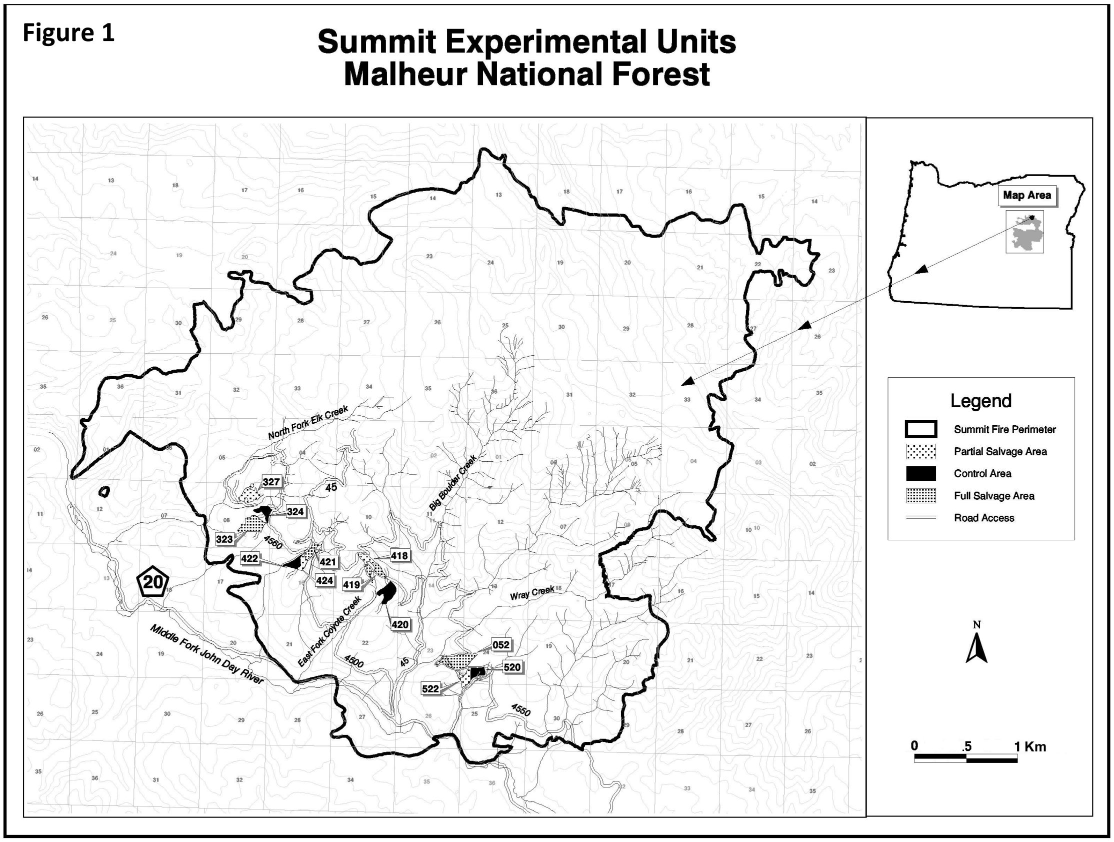
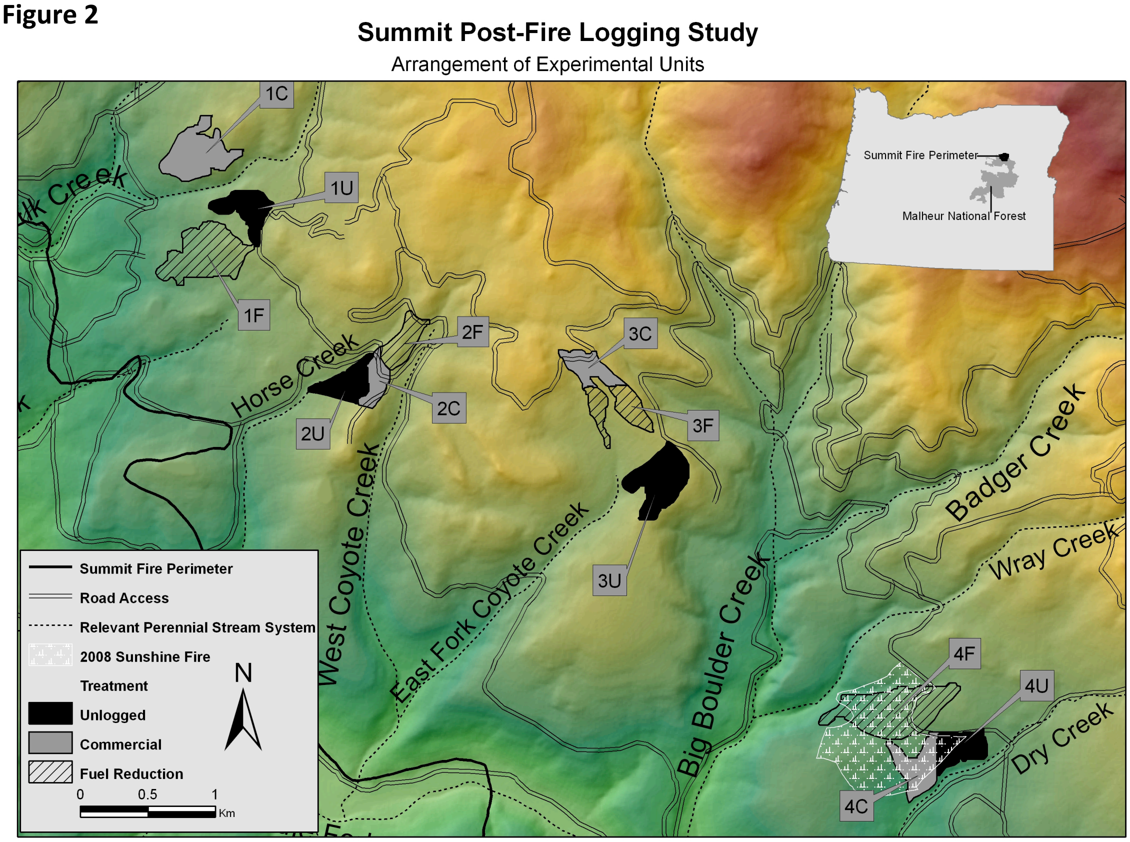


Figure 2



experiments. Several new studies have been conducted since then (see Lindenmayer et al. 2008 and Peterson et al. 2009 for more recent reviews), but only one *retrospective* study has reported on the intermediate-term effects of salvage logging on future re-burn severity (Thompson et al. 2007 – Silver and Biscuit Fires, SW Oregon). Importantly, no real-time *experimental* studies exist that evaluate the intermediate-term effects of re-burn severity in the context of salvage logging. Only two experimental studies have used *short-term* data to predict how post-fire logging may influence the future risk of a severe re-burn (Donato et al. 2006; McIver and Ottmar 2007). Interestingly, these two studies, conducted in two different seasonally dry forests in Oregon, present data that led to two somewhat different conclusions on the intermediate effects of post-fire logging on future fire risk. Donato et al. (2006) predicted that logging kills natural regeneration and increases slash fuel mass such that the young developing stand will be threatened in the intermediate term by a more severe recurring wildfire in logged stands. On the other hand, McIver and Ottmar (2007) observed no mortality of regeneration (logging was conducted before planting), and predicted that while slash fuel levels will remain higher in logged stands until 20 years post-fire, young developing seedlings in all stands would likely be too small during this period to withstand a recurring fire, even in unlogged stands. While it is very possible that these different conclusions are due to the different conditions at the two study sites (Biscuit Fire – SW Oregon; vs. Summit Fire – eastern Oregon), nonetheless re-measurement of study plots at Summit will definitely test the predictions of the McIver and Ottmar study. Finally, with the use of FVS-FFE, McIver and Ottmar (2007) also predicted that logging would not be likely to reduce extreme fire behavior after two or more decades, because the variable that showed the greatest projected long-term difference between unlogged and logged stands (10,000-hr fuels) does not contribute significantly to extreme fire behavior and fire severity, based on current models.

In any case, the intense public debate of the past 15 years on the practice of post-fire logging, coupled with the lack of reliable information on intermediate-term effects, points to the need for additional real-time studies that follow stands for many years after logging has occurred. We re-measured the same 273 plots used by McIver and Ottmar (2007) in their report on the short-term fuelbed and stand structure consequences of post-fire logging at Summit. That study was designed to evaluate the change due to logging on stand structure and fuels after a typical post-fire logging operation, and to predict future re-burn severity. The 16,000 ha Summit Fire was caused by a lightning storm on August 13, 1996, on the North Fork John Day Ranger District (Umatilla National Forest), burned south onto the Long Creek Ranger District of the Malheur National Forest, and was declared officially controlled on September 16, 1996 (USDA 1997). In the summer of 1997, three treatments (un-logged control, commercial, and fuel reduction) were randomly assigned to 12 experimental stands on the Malheur National Forest (Figure 2). Trees (both living and dead) and fuels (down wood and the forest floor) were measured pre- and post-logging, to test the “re-burn" hypothesis, or the extent to which removal of dead woody structure might change the present and future fuel complex. Since the 1999 post-logging measurements were taken, the Malheur National Forest has undertaken no additional silviculture or fuel reduction management in the Summit study area. On August 8, 2008 however, a moderate, grass-driven wildfire (Sunshine Fire) burned through most of one of the easternmost Wray Creek block (Figure 2), including 70% of the fuel reduction stand, 85% of the commercial stand, and 50% of the unlogged control stand. The capricious behavior of the Sunshine Fire distinguishes the Wray Creek block from the original replicated experiment, and turns it into a potential case study. Since the original experiment had four replicate blocks, what is now left is one fully replicated experiment of the original design (N=3), and one case study, in which all stands were initially burned in the severe 1996 wildfire, measured in 1997, logged in 1998, measured again in 1999, and burned again in 2008. This fortuitous circumstance thus not only allowed us to test predictions of the original study, but offered a controlled test of the logging treatment with an actual moderate wildfire.

This work has several important benefits for land managers. In general, it provides managers working in ponderosa pine-dominated dry forest systems with information they need to design future post-fire logging activities, and to plan programs to monitor vegetation after severe wildfire, with or without post-fire logging. In particular, we provide robust real-time information on how the fuel bed has changed 15 years after the fire, and whether logging increases intermediate-term wildfire risk due to higher slash fuel levels. We will compare regeneration success in stands that were left alone after fire (unlogged control) to stands that were logged. We will revise long-term predictions of logging effects on stand structure and potential fire severity. Finally, we will directly test predictions made by FVS-FFE at 10 years post-logging (1998-2008), using an actual wildfire as the testing tool (McIver and Ottmar 2007). More than anything else, replicated, experimental research like the Summit post-fire logging study become much more valuable if identical repeat measurements are taken into the future, because forest management is a long-term proposition, and there is no substitute for robust, real-time, experimental information on long-term effects of management activities.

STUDY OBJECTIVES, CHRONOLOGY, STUDY AREA, TREATMENTS, AND METHODS

Objectives

The present study examines the intermediate-term effects of Summit post-fire logging on stand structure, understory cover, and the fuel bed, and is focused on the following three objectives:

1) Test five predictions from the original study, using 2011 stand structure, understory cover, and fuel bed data collected in **Blocks 1-3** (unburned by the 2008 Sunshine Fire)(McIver and Ottmar 2007):
   a. There will be no among-treatment differences in live tree density, seedling or sapling density, cover of shrubs, forbs, or grasses, or in the mass of forest floor.
   b. Snag density will remain higher in unlogged units, but overall more than 75% of large snags (>30 cm DBH) will have fallen between 1999 and 2011, with ponderosa pine snags having fallen at a higher rate than Douglas-fir snags.
   c. Unlogged units will have higher mass of 1000-hr fuels (>7.62 cm diameter) compared to logged units, despite having had lower mass in 1999.
   d. About 1/3 of 1000-hr fuel will have decayed to the ‘rotten’ stage, regardless of treatment.
   e. Slash fuel mass will have increased for all treatments, but at a faster rate in unlogged controls, such that among-treatment differences will decline by 2011, compared to 1999.
2) Test two predictions from the original study, using 2011 stand structure, understory cover, and fuel bed data collected in **Block 4** (burned by the 2008 Sunshine Fire)(McIver and Ottmar 2007):

f. All trees planted after logging in 1999, as well as all natural regeneration, will have been killed in Block 4 plots that burned in the 2008 Sunshine Fire, regardless of logging treatment.
g. Snag density, vegetation cover, and woody fuel mass will be lower in all plots burned by the 2008 Sunshine Fire, regardless of logging treatment.

3) Measure the 2011 signal of 1998 post-fire logging on the Summit landscape, relative to the signals of the 1996 Summit Fire and the 2008 Sunshine Fire.

Chronology

1. 13 August – 16 September, 1996: Summit Fire burns 16,000 ha of seasonally dry forest on the Umatilla and Malheur National Forests.
2. June – November, 1997: study site, experimental units, and plots established for Summit Post-fire Logging study; pre-treatment data taken
3. June 1998 – April 1999: logging treatments implemented on 8 of 12 experimental units in Summit study area.
4. June – October 1999: short-term post-treatment data taken (1-year after logging)
5. January 2007: first paper on post-fire logging effects on fuels and stand structure published
6. 8-9 August, 2008: Sunshine Fire burns through most of Block 4, Summit study area
7. May – August 2011: intermediate term post-treatment data taken (13 years after logging)
8. 2014: second paper on post-fire logging effects on fuels and stand structure published

Study Area and Treatments

The study area is located on lands in the southern portion of the Summit Fire burned area (Figure 1: 44.680 – 44.715 Latitude; 118.694 – 118.765 Longitude), at relatively low elevations (1250 - 1400 m). The forests of the study area are considered to be in the 'warm/dry' biophysical type, historically dominated by ponderosa pine (*Pinus ponderosa*) in the overstory (with some representation of *Pseudotsuga menziesii* and *Abies grandis*), and pine grass (*Calamagrostis rubescens*) in the under-story. Soils are stony, clay loam to clay, with moderate to high surface erosion and compaction hazard, and low displacement hazard (McIver and McNeil 2006). Soils are derived from Clarno breccia parent material, but some soils have up to a 25 cm cap of Mt. Mazama ash, especially on their lower boundaries (USDA 1997). Like most of the Blue Mountains of northeastern Oregon, management activities of the last 80 years, namely fire suppression and the harvest of large pines, have had significant effects on vegetation and fire regimes within the Summit Fire project area (Agee et al. 1994). During pre-settlement times, the fire regime for ponderosa pine forests growing in the project area consisted of low severity fires (<20% mortality of large trees) occurring at intervals of between 15 and 25 years. As a consequence of fire suppression over the past 80 years, these forests have therefore missed between three and five wildfires in recent times, with the result that surface fuels have accumulated and become more continuous, and tree species such as grand fir and Douglas fir have become more prevalent. Coupled with the widespread removal of large pines over the same time period, these forest management practices have led to a shift toward higher wildfire severity compared to pre-settlement times (Agee et al. 1994).

Twelve experimental units ranging in size from 6-16 ha were established in four replicate blocks in August 1997 (Figure 1). Each block was located in a separate drainage, with perennial streams that flow past each block (Elk, Coyote, Wray Creeks) emptying into the Middle Fork of the John Day River. Nine of the study units (three complete blocks) were dominated by ponderosa pine, ranging from 64 to 100% overstory dominance in stem number (Table 1). One block (West Coyote) had one unit about equally dominated by ponderosa pine and Douglas-fir (421), and two units (422 and 424) dominated by Douglas-fir or grand fir.

Within each block, three treatments (control, commercial, fuel reduction) were assigned randomly to units, for a complete randomized block design. Control units received no logging treatment. The prescription for commercial units was to remove most (about 2/3) of dead merchantable trees, leaving at least 17 snags/ha, greater than 30 cm DBH. The prescription for fuel reduction units was to remove most dead merchantable trees (leaving minimum six snags per ha), and to remove most non-merchantable trees down to 10 cm diameter. The logging prescriptions were conceived such that the commercial treatment would reflect the results of a typical modern logging operation, while the fuel reduction treatment would result in sufficient fuel mass reduction such that the severity of a future re-burn might be significantly diminished. A total of 84 ha were logged between October 1998 and August 1999 (Table 1). Each commercial unit was entered once, while fuel reduction units were entered twice, once to remove the largest boles as part of a timber sale contract, and a second time to remove smaller boles as part of a service contract. Trees were felled by hand, whole trees (with limbs still attached) were cable-winched into skid trails with a tracked D6 Crawler-tractor[1], and retrieved to landings with a Caterpillar 518 rubber-tire grapple-skidder[1]. No additional treatment of the material left after logging (slash) occurred on any of the treated units. Pine seedlings were planted within each of the twelve experimental units, within two years after logging, at an average density of 960 stems/ha.

Methods and Materials

All variables were measured pre- and post-logging from the same permanently established grid points. A total of 277 grid points were laid out in the 12 experimental units in August 1997, between 14 and 47 points per unit (Table 1). Grid points were positioned 50 m apart, and at least 50 m from unit boundaries. Pre-treatment data were taken in the nine units of the Elk Ck, W. Coyote, and Wray Ck blocks between August and October 1997; the three units of the E. Coyote block were sampled in September 1998. Post-treatment data were taken from July to September 1999, immediately following the termination of logging (post-treatment year 1), and from June to early August 2011 (post-treatment year 13).

The same protocol was used on each of the three sampling occasions. Trees (DBH $\geq$ 10 cm) were tallied from within a 200 m^2 circular plot centered on each grid point. We recorded species, status (dead or alive), diameter at breast height, total height, and ladder fuel height (height to the lowest stem) for each tree. Basal area (m^2/ha) was calculated from tree diameter data. Saplings (young trees > 1.37 m height, but < 10 cm DBH) and seedlings (< 1.37 m height) were tallied in the 200 m^2 circular plot, and classified by species and status. Percent cover of shrubs, grasses and forbs was estimated visually for the entire 200 m^2 plot area.

Dead and down woody fuel was measured using the planar intercept method (Brown 1974). Three 30.5 m transects were originated from each grid point, the first selected randomly, and the other established at 120^o and 240^o from the first. Dead and down woody fuel less than 2.5

cm diameter was tallied for the first 1.9 m of each transect, and fuel between 2.5 and 7.6 cm was tallied along the full 30.5 m. Fuel > 7.6 cm diameter was tallied along the full transect and recorded as to species, decay class, and diameter at intersection point. Woody fuel masses were calculated using standard equations (Brown 1974). Litter and duff (forest floor) was measured to the nearest 0.25 cm depth at the 12, 18, and 24 m points on the transect. Depths were converted to mass using standard bulk density values (2.9 tons/ha/cm for litter, and 11.8 tons/ha/cm for duff; Ottmar et al. 1993).

Analysis of pre-treatment and post-treatment year 1 data have already been published (McIver and Ottmar 2007), and results of these analyses (1997 and 1999 measurements) will be compared to similar analyses of post-treatment year 13 data (2011 measurements) in the present paper. For the 2011 data, tree, snag, vegetation cover, and fuelbed variables were analyzed with analysis of variance (IBM-SPSS 2012), as a complete randomized block design [$Y_{ij} = \mu + T_i + B_j$ + random error]. Since the 2008 Sunshine Fire burned through nearly the entire eastern block (Block 4: Units 4U, 4C, 4F), we first analyzed the three western blocks (N=3), to document the process of stand collapse in unlogged and logged stands, and to determine the extent to which initial logging effects persisted or changed over the 12 year time period. We then analyzed the effects of a moderate severity re-burn that occurred 10 years after post-fire logging in the three experimental units of Block 4, in order to determine the extent to which post-fire logging influenced stand structure and fuel bed response to a re-burn. Since only one block was available for the re-burn analysis, with the individual plots serving as 'replicates', our inference space was necessarily restricted to block 4 only, and results interpreted as a case study. For both the replicated study (N=3) and the case study, we analyzed the status of variables in 2011, as well as the change in each variable from 1999 (post-treatment year 1) to 2011 (post-treatment year 13. All variables were normally distributed, and thus no transformations were made. Three pair-wise comparisons (un-logged v. commercial; un-logged v. fuel reduction, commercial v. fuel reduction) were planned apriori for each analyzed variable, and were examined by least-significant.

SCIENCE FINDINGS

As part of this final report, we developed 23 key science findings that arose from the analysis of short-term post-fire logging effects (measurements taken 1999, one year after logging; McIver and Ottmar 2007), and now from analysis of intermediate-term effects (measurements taken 2011, 13 years after logging; McIver and Ottmar 2014). Detailed findings, including support from other scientific literature, have been attached to the Access Database, which has been submitted to the US Forest Service R&D Data Repository, and will also be published on the FRAMES website, when the database is accepted for publication. Here we provide each finding and its management implication, in bulleted form:

FINDINGS ON SHORT-TERM EFFECTS -- FROM MCIVER AND OTTMAR (2007)

1) Finding: Logging between June 1998 and April 1999 reduced mean basal areas to 46% in four stands experiencing a single entry to remove merchantable timber (commercial treatment), and down to 25% in four stands that experienced two entries, the first to remove merchantable timber, and the second to reduce fuels (fuel reduction treatment). **Management Implication**: Post-fire logging practices and prescriptions have varied widely over the past 30 years (McIver and Starr 2000, 2001; Peterson et al. 2009). Thus, while basal area reduction in the Summit Study falls within the range reported for some other studies, including those on wildlife (Blake 1982; Caton 1996; Saab and Dudley 1998), vegetation (Blake 1982), and fuels/stand structure (Donato et al. 2013), results from this study should be applied to other post-fire logging studies with caution. At the very least, scientists should report detailed information not only the intended logging prescription, but data on how structure was actually changed.

2) Finding: Logging reduced tree density, especially in the intermediate size class (23-41 cm DBH) for the commercial treatment, and in both the smallest (< 22 cm DBH) and intermediate size classes for the fuel reduction treatment. **Management Implication**: Stem density reduction followed prescription, and was consistent with the tendency for loggers to take the largest stems possible given commercial constraints and timber sale guidelines; smaller non-commercial stems were only taken in the fuel reduction treatment, in which the logger was paid through a separate service contract.

3) Finding: Logging reduced large snags (> 30 cm DBH): while unlogged controls averaged 64 snags/ha in the summer of 1999, commercial stands averaged 23 snags/ha, and fuel reduction stands averaged only 4 snags/ha. **Management Implication**: Logging reduced large snag densities far below those observed one year post-logging in unlogged stands, thereby reducing the habitat quality of logged stands for cavity-nesting bird species.

4) Finding: Logging did not change ladder height or tree species composition. **Management Implication**: This is not surprising, as post-fire logging is not typically conducted as a means to reduce the likelihood that surface fires will enter tree crowns.

5) Finding: Logging increased total fuel mass, particularly in the slash fuel size class (1 to 100-hr fuels, < 7.62 cm diameter), with fuel reduction stands averaging 5.4 Mg/ha of slash fuel, commercial units 4.3 Mg/ha, and unlogged controls averaging 1.5 Mg/ha. **Management Implication**: If managers are interested in fuel reduction as an objective for a post-fire logging operation, then the choice of logging practice may be important. For example, whole tree yarding may be preferable to practices that leave excessive slash in the woods.

6) Finding: Logging activity did not cause short-term changes in the mass of duff or litter. **Management Implication**: Logging activity at Summit generally took place over dry or frozen ground, thus protecting the soil from the most egregious machine effects, such as compaction and displacement.

7) Finding: FVS-FFE model projections indicate that logging-induced differences in slash fuel would be sustained until about 15 years post-logging, but if a re-burn of moderate intensity were to occur during that time, all seedlings and saplings that began growth post-fire would be killed, even in un-logged stands, due to the influence of other components of the fuel bed (grasses, shrubs). **Management Implication**: Post-fire logging in ponderosa pine-dominated stands would have little influence on re-burn mortality of a young regenerating stand if the re-burn were to occur within 15 years after logging. This is because other components of the fuel bed would be adequate to generate flame heights high enough to kill trees less than 15 years old.

8) Finding: FVS-FFE model projections indicate that standing dead structure in all stands would collapse quickly, with 80% of snags falling within 15 years post-logging. **Management Implication**: Despite the fact that fire-generated snags have a short lifespan, managers should be aware that this resource, however fleeting, is of critical importance to a variety of wildlife species that are dependent on stand-replacement fire.

9) Finding: Stand collapse would be projected by FVS-FFE to result in accumulation of 1000-hr fuels (woody fuels > 7.62 cm diameter), especially in unlogged stands, such that unlogged stands would have 2 or 3-fold greater masses of heavy fuel at 25 and 50 years post-logging. **Management Implication**: Because post-fire logging removes many of the larger dead stems in burned stands, it can be considered a fuel reduction practice. However, whether or not fuel reduction of this kind has any practical implications remains to be seen. For example, the much greater mass of logs projected to accumulate in unlogged stands in the several decades after logging would *not* be expected to change fire behavior should a re-burn occur during that time. Managers should probably think about the log resource from a multiple-use point of view that includes considerations of the fuelbed, as well as the value of logs in terms of forest soil productivity and wildlife habitat.

10) Finding: Despite differences between unlogged and logged stands in heavy fuel accumulation for decades post-fire, FVS-FFE would not predict concomitant differences in young tree mortality should a re-burn occur, because coarse woody debris does not contribute to the kind of fire behavior that tends to kill trees. **Management Implication**: As mentioned above, current fire behavior models -- all based on Rothermel's fire spread equations -- are not sensitive to coarse woody debris mass. That said, managers should be aware of the possibility that should a re-burn occur within a few decades after stand replacement fire, mortality to a developing stand could still result from smoldering combustion of logs, especially if a large proportion of ground surface area were covered by them, on which is growing the developing new stand.

Findings on Intermediate-Term Effects -- from McIver and Ottmar (2014):

1) Finding: Mean basal area and density of trees that survived the 1996 Summit Fire remained unchanged from that measured in 1999, one year post-fire logging. **Management Implication**: Significant delayed mortality from the 1996 Summit Fire was not observed in the Summit stands.

2) Finding: Mean basal area of dead trees in 2011 declined to about one-third that observed in 1999, and was proportional to logging treatment. **Management Implication**: Post-fire logging did not change the *rate* at which dead trees fell, when measured between two points in time (1999 and 2011). This does not mean however, that fall rates *within* that time period were similar (see finding below on the proportion of sound versus rotten coarse woody debris in logged v. unlogged stands).

3) Finding: Ponderosa pine snags (dead trees > 30cm DBH) fell at a faster rate than Douglas-fir snags, declining by 2011 to 23% of the density measured one year after logging in 1999, compared to 34% for Douglas-fir. **Management Implication**: While ponderosa pine snags may have great value as wildlife trees while they last, they have a relatively short lifespan, with the majority projected to stand < 10 years after creation by fire.

4) Finding: Snag density, especially Douglas-fir, remained higher in unlogged stands 13 years after post-fire logging. **Management Implication**: Post-fire logging in the lower elevation ponderosa-pine dominated stands at Summit, caused a relative snag deficit in logged stands that has persisted up to 13 years post-logging. As a consequence, cavity-nesting birds would likely perceive the logged landscape as relatively less suitable for foraging and nesting, compared to unlogged stands, for at least 13 years after logging.

5) Finding: Mean forest floor mass declined for all treatments, but much more rapidly in logged stands. This is probably because of additional bark slough arising from higher mass of coarse woody debris in unlogged stands. **Management Implication**: We do not believe that differences in the mass of forest floor due to logging treatment is significant for these stands, because the additional bark slough causing this difference is probably not meaningful in terms of stand productivity.

6) Finding: Slash fuel mass tripled between 1999 and 2011 in unlogged stands, but decreased slightly in both commercial and fuel reduction logged stands, with the result that mean mass of forest floor was equivalent for all treatments by 2011. **Management Implication**: By year 13 after post-fire logging, the type of woody fuel most responsible for variation in fire behavior converged in logged versus unlogged stands, indicating that differential logging effects on short-term risk disappeared after that amount of time.

7) Finding: Both sound and rotten 1000-hr woody fuel (> 7.62 cm diameter) increased markedly by 2011 in all stands regardless of treatment, as over 75% of trees killed by the 1996 Summit Fire fell down. **Management Implication**: Although logging will reduce the *quantity* of heavy woody fuels that eventually arrive on the forest floor, post-fire logging at Summit was selective enough to leave a substantial quantity of standing dead stems, which still provided ample fuel resource for smoldering combustion should a re-burn occur.

8) Finding: Unlogged stands contained much more sound 1000-hr fuel by 2011, compared to unlogged stands. **Management Implication**: This result was unexpected, because it suggests that either the *rate* of stand collapse differs for logged and unlogged stands (decay is only assumed to begin when stems hit the ground), or that decay rates differ, once snags have hit the ground. Possible reasons for this difference include: 1) Machine vibration loosened dead stems in logged stands, which then collapsed at a higher rate compared to unlogged stands; 2) High stem density in unlogged stands may have protected stems from windfall in the initial stages of stand collapse; and 3) The volume of woody material on the ground in unlogged stands may have overwhelmed bacterial and fungal decay populations, or the insect populations that aid decay by comminution of sound wood.

9) Finding: Roughly half of coarse woody debris present in 2011 was decayed enough to be classified as 'rotten'. **Management Implication**: If these current decay rates continue, all coarse woody debris in the Summit stands will be rotten by 2025 (~30 years after the Summit Fire), indicating a somewhat faster decay rate than predicted.

10) Finding: Unlogged stands contained about twice the mass of coarse woody debris greater than 15 cm diameter as compared with either commercial or fuel reduction stands. **Management Implication**: Logging cut the quantity of coarse woody debris habitat in half, as measured 13 years after post-fire logging. This could have potential implications for wildlife species that use this resource as foraging habitat (i.e. pileated woodpeckers, black bears, other birds and mammals that forage in coarse woody debris for beetle and other insects).

11) Finding: Logged stands that were entered twice (fuel reduction stands) had about 1/3 the density of sapling stems by 13 years post-fire logging, compared to unlogged stands. **Management Implication**: Since most saplings observed in 2011 were probably planted after the 1996 Summit Fire, managers might consider delaying the planting of young trees until after logging has occurred.

12) Finding: The 2008 Sunshine Fire, which burned through nearly one complete block within the Summit Study Area, erased most of the effects of the 1998 post-fire logging operation: snags were reduced to < 0.5 ha^{-1} for all treatments, forest floor and fuel mass were reduced to near 0, log mass declined to about 1/4 that observed in stands unburned by the Sunshine Fire, and shrubs and seedlings were nearly eliminated. **Management Implication**: The effect of the 2008 re-burn on regeneration was as predicted after measurements taken in 1999 (McIver and Ottmar 2007): despite higher initial slash mass in logged stands, very few of the seedlings and saplings planted after the 1996 Summit Fire survived the moderate surface fire of 2008; thus, post-fire logging in this case did not increase fire risk for the developing stand.

SUMMIT DATA MANAGEMENT

The Senior Principal Investigator throughout the study was James McIver, who worked for the PNW Research Station from 1996 through early 2005, and for Oregon State University from mid-2005 to the present (2014). McIver was primarily responsible for study design and implementation, data entry and management for the 2011 data set, and for data analysis, interpretation, and publication of both technical papers. The Co-Principal Investigator was Roger Ottmar, who has worked for the PNW Research Station from 1996 to the present time (2014). Ottmar was primarily responsible for data collection, data entry and data management for the short-term study conducted between 1997 and 1999, for data collection for the intermediate-term study of 2011, for general consultation on fuel data issues for all phases of the study, and for editing of both technical papers on fuel and stand structure. National Forest personnel involved in the study include the following: 1) 1996-2000: Hugh Snook, Eric Wunz, Barb Boaz (Malheur National Forest – 541-575-3000), and Glen Fisher (Umatilla National Forest – 541-278-3716); 2) 2010-2014: Eric Wunz, Roy Walker (Malheur National Forest – 541-575-3000).

Three different field crews were responsible for data collection: 1) in 1997, we used a crew of two or three, comprised at various times of the following individuals: D. Motanic, K. Brock,

M. Mosley, J. Traylor, R. Bullock, M. Wall, and J. Miller; 2) in 1999, we used a crew of two or three, comprised at various times of the following individuals: M. Nicodemus, D. Robison, D. Motanic, M. Lenz, and A. Miles; and 3) in 2011, we used a crew of four, supervised by Bob Vihnanek (PNW Research Station), and comprised of individuals with the following initials: JD, LG, JM, CB, SW. Copies of all data sheets, with initials or names of measurement personnel, are held as supplemental material at Oregon State University, at the Eastern Oregon Agricultural Research Center, Union, Oregon, 97883 (Office of James McIver; 541-910-0924), and at the Seattle Lab of the PNW Research Station, Seattle, WA (Office of Roger Ottmar; 206-732-7826). Unit maps showing all Plot locations are provided as supplemental information with the current database product.

For the short-term study (measurements in 1997 and 1999), data were collected, entered, proofed, validated, and summarized to the Unit-level by the Co-Principal Investigator (Ottmar) and his crew. Spreadsheets of these Unit-level data were then emailed to the Senior Principal Investigator (McIver) for analysis. For the intermediate-term study (measurements in 2011), data were collected by Bob Vihnanek and his crew, and field sheets were then mailed to McIver and his crew (Karen Erickson), for data entry, proofing, and validation. This explains why the 1997 and 1999 data are presented here as spreadsheets, summarized to the Unit-level, while the 2011 data are presented here in both a database containing Plot-level data, and presented in spreadsheet format, also at the Plot-level.

Summit Database Contents.

All data are contained within a Microsoft Access database. When viewed in Microsoft Access 'Custom' navigation mode, the contents of the Summit Database are organized in the following way:

1) Introduction, which presents the organization of the database product.
2) Meta-Data section, which includes: a) MetaVist file, which presents most meta-data information in a format compliant with FGDC standards, with output in XML format; b) A Meta-data spreadsheet, which contains definitions of all variables, and provides details of variances in treatment implementation, protocols, and basic experimental design; c) Summit project maps and two tables that provide critical information about the Summit Experimental Units.
3) Database in Microsoft Access, consisting of a set of linked tables, which contain information on site design, treatments, data on fuels, vegetation, and stand structure.
4) A set of Summit Data Summary Spreadsheets, representing 1997 and 1999 (Unit-level) and 2011 (Plot-level) data summarized from data entered from the field sheets. These are presented in documented spreadsheet format.
5) Publications, including PDFs of the two technical papers referring to fuels and stand structure (McIver and Ottmar 2007, 2014), as well as the two additional publications on sediment transport (McIver 2004) and soil disturbance (McIver and McNeil 2006), generated from other data collected as part of the overall Summit Study.
6) Key findings of the Summit Project thus far, extracted from the published technical papers.

THE DELIVERABLES CROSSWALK TABLE

Deliverable Type (See Proposal Instructions)	Description	Delivery Dates
Fact Sheet (aka *Fire Science Brief*)	Summarizes principle findings in context of scientific literature; designed for use in NEPA Input into JFSP Fire Science Digest, written by Tim Swedberg	Conversations with Tim Swedberg, summer and fall 2013
Presentations and field trips to Malheur, Umatilla, and Wallowa-Whitman Forests	Using both presentations and field trips, Senior PI will present findings to the primary clients (National Forests of NE Oregon)	Malheur NF: February 2014 Umatilla NF: March 2014 Wallowa-Whitman NF: April 2014
IAWF Conference	Co-PI will present at the I4th IAWF Conference	May 2014, Missoula, MT
SAF Conference	Senior PI will present at annual SAF conference	September 2014, Salt Lake City, UT
AFE Conference	Senior PI will present at AFE Conference	May 2014, Missoula, MT
Data Set on FRAMES	Fully documented Data Set, including 1997, 1999, and 2011 data, posted on FRAMES web site Submitted to the Forest Service R&D Data Repository; link to be provided on FRAMES when Repository review is completed	Submitted 30 December, 2013
Scientific Papers	Describe all primary findings; replicated experiment published in *Forest Ecology and Management;* case study published as *PNW Station GTR* Both replicated experiment and case study to be published in *Forest Ecology and Management*	Submitted to FS policy review 30 December, 2013
Final Report	Summary description of findings to JFSP	31 December 2013

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